Charm and QCD at CLEO-III and CLEO-c

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Physics topics:

1) Measurement of $\Xi_c^0 \rightarrow pK^-K^-\pi^+$  
   (CLEO-III)

2) Form factors in $D^0 \rightarrow \{\pi^-, K^-\}e^+\nu$  
   (CLEO-III $\Rightarrow$ CLEO-c)

3) Disentangling glueballs and $q\bar{q}$ states  
   (CLEO-c)

XXXIX Rencontres de Moriond  
QCD and High Energy Hadronic Interactions  
28 March - 04 April, 2004
1) Measurement of $\Xi^0_c \rightarrow pK^-K^-\pi^+$


Physics: The decay $\Xi^0_c \rightarrow pK^-\bar{K}^*(892)^0$ cannot proceed through external $W$ decay, so it is “color suppressed”.
$\Rightarrow$ Want to separate it from nonresonant four-body decays.

Measured $\Xi^0_c \rightarrow pK^-K^-\pi^+$ rate relative to $\Xi^0_c \rightarrow \Xi^-\pi^+$

Needs extensive $p, K, \pi$ particle identification made possible by RICH in CLEO-III

Only previous result: ACCMOR 1990 (four events, all $\bar{K}^*$)
RESULTS: $\Xi^0_c$ Decay

$\Xi^0_c$ Decay modes

$K^-\pi^+$ mass distribution:

$\mathcal{B}(\Xi^0_c \rightarrow pK^-K^-\pi^+)/\mathcal{B}(\Xi^0_c \rightarrow \Xi^-\pi^+) = 0.35 \pm 0.06 \pm 0.03$

$\mathcal{B}(\Xi^0_c \rightarrow pK^-K^-\pi^+; \text{No } K^*)/\mathcal{B}(\Xi^0_c \rightarrow \Xi^-\pi^+) = 0.21 \pm 0.04 \pm 0.02$
2) Form Factors in $D^0 \to \{\pi^-, K^-\} e^+ \nu$

New CLEO-III analysis to be published soon.

For $q^\mu \equiv p^\mu (W^+)$ have

$$\frac{d\Gamma}{dq^2} = \frac{G^2}{24\pi^3} |V_{cq}|^2 p^3 |\mathcal{F}(q^2)|^2$$

Note: First measurement of $D \to \pi e \nu$ form factor shape!

Plus: New result for $\mathcal{B}(D^0 \to \pi e \nu)/\mathcal{B}(D^0 \to K e \nu)$
Signal and Background in CLEO-III

Identify $D^0$ from $D^*^+ \rightarrow \pi^+_{\text{slow}} D^0$

Kinematic variable used is $\Delta M \equiv M(D^*) - M(D)$

$D^0 \rightarrow K^- e^+ \nu$

Mid $q^2$ Bin
C.L. = 28%

$D^0 \rightarrow \pi^- e^+ \nu$

Mid $q^2$ Bin
C.L. = 52%

$\Rightarrow$ The challenge for $D \rightarrow \pi e \nu$ is significant!
RESULTS: $D^0 \rightarrow \pi^- e^+ \nu_e$ Normalized $q^2$ Distribution

All results are preliminary!!

Form factor models

Binned data points

Plus: $\mathcal{B}(D^0 \rightarrow \pi e \nu)/\mathcal{B}(D^0 \rightarrow K e \nu) = 0.097 \pm 0.010 \pm 0.010$
The CLEO-c Program

Prologue: Completed Υ(1S), Υ(2S), Υ(3S), Υ(5S), Λ_b¯Λ_b runs, and short runs carried out at ψ'(3686), ψ''(3770), . . .

Dedicated Running in ~1 Year Blocks

Act I: ψ(3770) 3 fb⁻¹ ⇒ 30M Events (for σ_{D¯D} = 10 nb) ⇒ 6M Tagged D decays

Act II: √s ≈ 4.1 GeV 3 fb⁻¹ ⇒ 300K Tagged D_s decays

Act III: J/ψ(3097) 1 fb⁻¹ ⇒ 1 Billion J/ψ decays

Act I is already underway!

Epilogue: ψ'(3686), R, . . . depending on time and resources
CLEO-c event: $e^+e^- \rightarrow \psi''(3770) \rightarrow D^0 \bar{D}^0$

$D^0 \rightarrow K^-e^+\nu_e$ \quad $\bar{D}^0 \rightarrow K^+\pi^-$
Signal and Background for $D^0 \rightarrow \pi^- e^+ \nu$ in CLEO-c

Monte Carlo
Assumed 1 fb$^{-1}$
Particle ID cuts applied

Data (Preliminary!)
Analyzed 60 pb$^{-1}$
No particle ID cuts (yet)
3) Disentangling Glueballs and $q\bar{q}$ States

Radiative $J/\psi$ decay is an excellent glueball filter

$$J/\psi \rightarrow \gamma gg \rightarrow \gamma + \text{glueball}$$

Lattice QCD says the lightest glueball is a scalar meson with a mass between 1500 and 1700 MeV/$c^2$.

The quark model says there are two scalar mesons in this mass region (i.e. $|u\bar{u} + d\bar{d}\rangle \equiv |n\bar{n}\rangle$ and $|s\bar{s}\rangle$).

Three states have been observed:

$$f_0(1370), f_0(1500), f_0(1710)$$

$\Rightarrow$ What is the mixture of $q\bar{q}$ and glueball?
Mark-III (SPEAR): $6 \times 10^6 J/\psi$

$$J/\psi \rightarrow \gamma X, \text{ where } X \rightarrow \ldots$$

Data Points: A Bin-by-Bin (i.e. Mass Independent) Fit
Solid Lines: A Mass Dependent Fit to the Data Points

No sign of the $f_0(1500)$?
Radiative Decays as a Probe of $q\bar{q}$-Glueball Mixing


\[ M(\text{glueball}) < M(n\bar{n}) \equiv \text{“L”} \]
\[ M(n\bar{n}) < M(\text{glueball}) < M(s\bar{s}) \equiv \text{“M”} \]
\[ M(\text{glueball}) > M(s\bar{s}) \equiv \text{“H”} \]

<table>
<thead>
<tr>
<th>Radiative Decay Widths in keV</th>
<th>$\Gamma_{\text{Tot}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>$f_0 \rightarrow \gamma \rho(770)$</td>
</tr>
<tr>
<td>$f_0(1370)$</td>
<td>L 443</td>
</tr>
<tr>
<td>$f_0(1500)$</td>
<td>L 2519</td>
</tr>
<tr>
<td>$f_0(1710)$</td>
<td>L 42</td>
</tr>
</tbody>
</table>

Excellent discrimination!

⇒ Expect $B(f_0 \rightarrow \gamma V) \approx 10^{-2}$ to $10^{-4}$.

For $B(J/\psi \rightarrow \gamma f_0) \approx 10^{-3}$ we should acquire
10,000 to 100 events for $10^9 J/\psi$. 
Summary and Outlook

• CLEO-III is still producing results

  *This Conference*: M. Shepherd and J. Duboscq
  See also: M. Dubrovin, Moriond QCD 2003,
  including $D \rightarrow \pi\pi\pi$, $D \rightarrow K\pi\pi$, $D \rightarrow KK\pi$, ...

• CLEO-c well underway towards 3 fb$^{-1}$ at $\psi''(3770)$

  Large sample of *clean* $D\bar{D}$ pairs
  Hadronic *and* electroweak physics analyses started

• Strong future program for CLEO-c

  $\gamma D\bar{D}$ and $D_s^+D_s^-$ production
  Goal of $10^9 J/\psi$ events
  Other physics opportunities

*Stay Tuned!*